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The secondary outcome of public health measures amidst the COVID-19 pandemic in the spread of other respiratory infectious diseases in Thailand

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ABSTRACT

The coronavirus disease 2019 (COVID-19) has promoted stringent public health measures such as hand hygiene, face mask wearing, and physical distancing to contain the spread of the viral infection. In this retrospective study, the secondary outcomes of those public health measures on containing other respiratory infections among the Thai population were investigated. Hospitalization data spanning from 2016 to 2021 of six respiratory infectious diseases, namely influenza, measles, pertussis, pneumonia, scarlet fever, and tuberculosis (TB), were examined. First, the expected respiratory infectious cases where no public health measures are in place are estimated using the seasonal autoregressive integrated moving average (SARIMA) model. Then the expected number of cases and the observed cases were compared. The results showed a significant drop in the incidence of respiratory infectious diseases by an average of 61%. The reduction in hospitalization is significant for influenza, measles, pertussis, pneumonia, and scarlet fever ($p < 0.05$), while insignificant for TB ($p = 0.54$). The notable decrease in the incidence of cases is ascribed to the implementation of public health measures that minimized the opportunity for spread of disease. This decline in cases following relaxation of pandemic countermeasure is contingent on its scope and nature, and it is proof that selective physical distancing, hand hygiene, and use of face masks in public places is a viable route for mitigating respiratory morbidities.

1. Introduction

Since the declaration of the coronavirus disease 2019 (COVID-19) as a pandemic by the representatives of WHO on March 11, 2020, various countries globally have adopted an array of mostly similar measures to contain its spread. Some of the precautionary measures encouraged and implemented included hand hygiene, use of face masks, varying degrees of lockdown measures (e.g., closures of schools and businesses, travel restrictions, and the issue of stay-at-home orders and/or work from home, etc.) and physical distancing measures such as forbidding large gatherings [1–4]. A systematic review of the effectiveness of public health measures and non-pharmaceutical interventions confirms their importance in curbing the rates of infection and mortality linked to the COVID-19 pandemic [5]. The ancillary benefits of these preventive measures have been reported to lead to substantial decreases in respiratory diseases like influenza with overlapping transmission dynamics [6,7]. A study from South Korea reported an overall decline in the mean positivity rate for several respiratory viruses from 54.7% in 2010–2019 to 39.1% in 2020 [8]. The authors of this report noted that the largest decreases were observed for the influenza virus. In line with this study, Sun et al. [9] also observed a massive reduction (47.7%–1.2%) in the incidence of influenza cases in the first six weeks of 2020 compared to October 6 of the previous year.

In the backdrop of findings such as those previously cited, it is vital to assess the impact of public health measures on respiratory infectious diseases in Thailand. Coronavirus disease 2019 infection was first reported in Thailand on January 13, 2020, making it the first country outside of China to report a case [10]. The number of infected cases slowly increased in the months that followed up until mid-March [11]. Post mid-March, the number of cases spiked at an average rate of 25.1% per day until March 26. A strong and rapid governmental response and public health intervention quickly followed to alter the trend. The turn of April was marked by contact tracing, a full-scale nationwide lockdown, curfews, mandatory quarantine for international travelers and compulsory mask wearing [12,13]. Prior to the government's edict on compulsory mask wearing, it was already customary for citizens to wear masks in public (as early as January) and practice hand hygiene due to mass media campaigns in the light of rising cases in the early phase of

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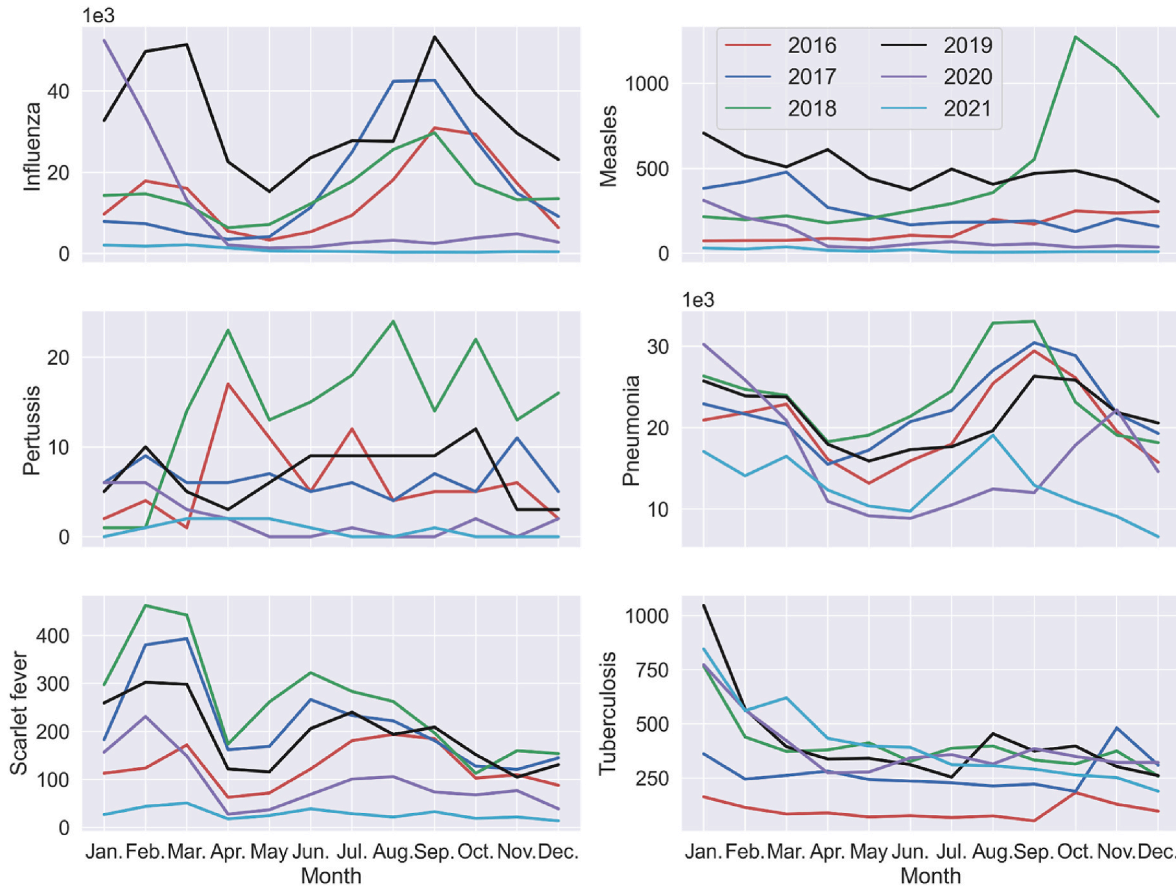

Fig. 1. Monthly hospitalization of respiratory diseases from 2016 to 2021.

the first wave and seasonal $PM_{2.5}$ pollution. Economic activities resumed in May, coinciding with the first of five progressive easing phases that culminated in the official exit of the first wave on July 31, 2020 [14]. The first wave of the pandemic has since been followed by a second, third, fourth and fifth waves occurring in the months of December 2020, April 2021, July 2021, and January 2022, respectively [12,15,16]. Following the resumption of economic activities, the government has embraced a mixture of strategies such as lock down of specific areas, active case finding (ACF) in the affected localities, temporary closure of risk-prone venues, regulation of mass gatherings alongside increasing vaccination rates nationwide. At the level of individuals, most Thai people still maintain the habit of wearing masks and practicing hand hygiene. Considering how Thailand fared in its handling of the different COVID-19 waves, this retrospective study aims to examine how public health measures enacted affected the incidence of various infectious respiratory diseases. A recent study done by Prasertbun et al. [17] showed that pneumonia and influenza have decreased during the pandemic era compared to the pre-pandemic era. The current study stands out in that it includes a more extensive list of diseases and makes comparisons between situations wherein no public health measures are implemented as opposed to when they are implemented.

2. Methodology

This study was retrospective, investigating the incidence of various respiratory diseases during public health measures put in place due to the COVID-19 pandemic. The reported cases of respiratory infectious diseases, namely influenza, measles, pertussis, pneumonia, scarlet fever, and tuberculosis (TB), were obtained from National database for disease surveillance repository provided by the Center of Epidemiological Information, Bureau of Epidemiology, Ministry of Public Health. The surveillance report is submitted by each provincial public health office, hospital, and health stations every week [18]. While the database does not specifically account for the pathogens responsible for pneumonia, studies suggest older adults are afflicted by the gram-negative bacteria, *Klebsiella pneumoniae* and *Pseudomonas aeruginosa* [19]. In children, viruses like respiratory syncytial virus (RSV), rhinovirus and adenovirus are primarily responsible [20]. The dataset for influenza, measles, pertussis, pneumonia, scarlet fever, and TB ranges from 2016 to 2021, while that for COVID-19 ranges from 2020 to 2021. Prior to statistical analysis, time-series plot was analyzed for seasonality and trend of the observed cases of all types of respiratory diseases studied.

The respiratory infection cases from 2016 to 2019 represent the number of cases with no public health measures such as hand hygiene, face mask wearing, and physical distancing. On the other hand, respiratory infection hospitalizations for 2020 and 2021 represent the disease incidence when public health measures are put in place. Besides public health measures such as face mask wearing, hand hygiene, and physical distancing, there are many factors that can affect the number of yearly hospitalizations such as population growth, humanitarian response, infrastructure, living conditions, and public health systems. In order to account for those risk factors, respiratory infectious cases were forecasted for 2020 and 2021 based on pre-pandemic observed data (2016–2019) using seasonal autoregressive integrated moving average (SARIMA) model. In addition, average pre-pandemic (2018–2019) cases of respiratory infectious diseases were also compared to the number of cases during the COVID-19 pandemic (2020–2021).

2.1. SARIMA model and statistical analysis

The SARIMA method models the next step in the sequence as a linear function of the differenced observations, residuals, differenced seasonal

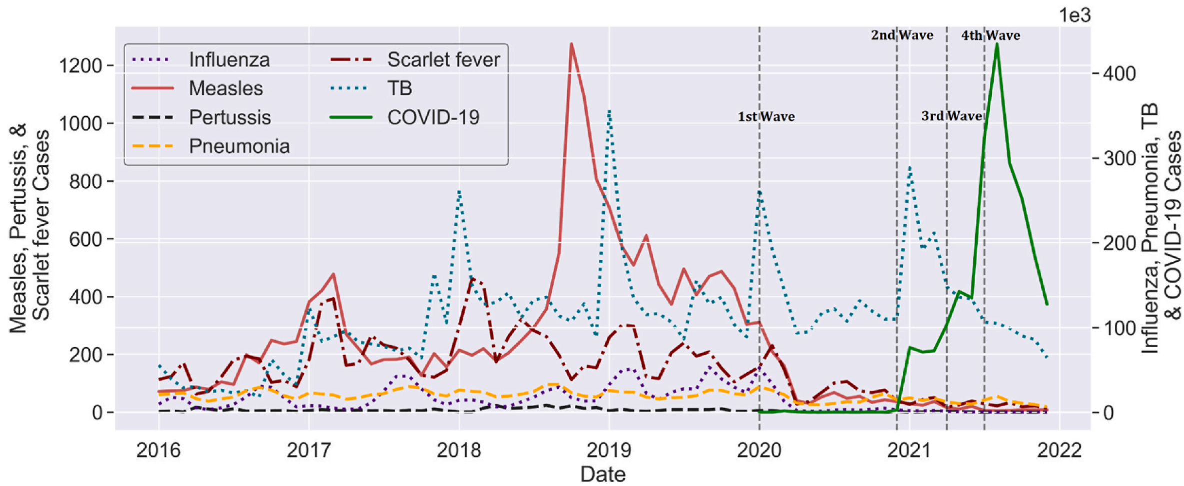

Fig. 2. Monthly incidence of respiratory infectious diseases between 2016 and 2021.

observations, and seasonal residuals at prior time steps. A major advantage of SARIMA is that it takes account of the seasonal cycles and trend of the observed data. The SARIMA model is generally structured as SARIMA (p, d, q) × $(P, D, Q)_m$, where m is the seasonal factor, p is trend autoregressive order, d is trend difference order, q is the trend moving average order, P is seasonal autoregressive order, D is seasonal difference order, and Q is the seasonal moving average order. The mathematical expression and a detailed explanation of the SARIMA model are given elsewhere [21].

The time-series forecasting of respiratory infectious cases was performed by dividing the data into training and testing datasets. The training data set comprises the data from 2016 to mid-2019 (32 months), while the testing data set comprises the remaining six months of 2019. The parameters for the SARIMA model were computed based on the Akaike information criterion (AIC), where the lowest AIC value indicates the best fit. After the parameters were chosen, the SARIMA model was performed to estimate the incidence of respiratory infectious diseases in 2020 and 2021, assuming no public health measures were imposed. Finally, the model diagnostic was performed to ensure none of the model assumptions are violated. Once the model assumptions were satisfied, the model was used to forecast future values.

Furthermore, the difference in monthly observed incidence of respiratory infectious diseases during the COVID-19 pandemic (2020–2021) and the estimated number of cases for 2020–2021 was computed using a two-tailed non-parametric Mann-Whitney *U* test at a significance level of 0.05. In addition, a correlation analysis was performed among the types of respiratory diseases and COVID-19 cases to examine the relationship. All statistical analysis, SARIMA model and plots were performed using Python programming.

3. Results and discussion

The monthly variations of respiratory infectious diseases of influenza, measles, pertussis, pneumonia, scarlet fever, and TB between 2016 and 2021 are shown in Fig. 1. Additionally, the statistical test for the average incidence of respiratory infectious diseases between the pre-pandemic and the pandemic period are shown in Table S2. The most interesting aspect of this time-series graph is that hospitalizations for influenza, measles, pertussis, pneumonia, and scarlet fever cases dropped significantly in 2020 and 2021. For example, the peak (53,339) cases of influenza pre-pandemic were in September 2019, and the cases sharply dropped to 304 in the same month in 2021. Similarly, the peak cases of scarlet fever (462), pertussis (24), pneumonia (33,061), and measles (1,274) were seen in February, August, September, and October 2018, respectively. Surprisingly, the number of hospitalizations for scarlet fever, pertussis, pneumonia, and measles dropped to 44, 0, 12,936, and 8, respectively, in the same months in 2021. On the other hand, there were changes in the trend for the prevalence of TB over the years. For example, total hospitalization of TB gradually increased from 2016 to 2019 by 1,199 to 5,047, then fell off to 4,708 and 4,866 in 2020 and 2021, respectively. Tuberculosis cases during the pandemic (2020–2021) are slightly lower (−2%) than during the pre-pandemic period (2018–2019). Basing the seasonality of TB on the six-year period of the current study (2016–2021), incident rates were highest in the first month of four (2018–2021) out of six of these years. A 2010 study on the incidence of tuberculosis over a six-year duration in southern Thailand, found that the incidence rates of the disease were higher in the first quarter of the year [22]. While it is worth noting that the seasonal patterns attributed to acute respiratory diseases are linked heavily to the differences in transmission dynamics, the mechanisms governing the seasonality of TB are far more complex [23]. This is partly due to the length and variation of incubation period and by contributions of exogenous and endogenous reactivation infections.

The time-series plot of the respiratory infectious diseases also shows seasonal patterns of hospitalization for all diseases investigated (Fig. 2). Moreover, there is an increasing trend over the years from 2016 to 2019 in the incidence of influenza, measles, and TB. In contrast, pertussis, pneumonia, and scarlet fever showed an increasing trend until 2018 and then started to show a decreasing trend in 2019 (Fig. S1). During the COVID-19 pandemic starting from the first wave, all respiratory infectious diseases with the exception of TB, showed an abrupt decrease. The abrupt change indicates the effect of the nonpharmaceutical measures in containing respiratory diseases. These results reflect those of Friedrich et al., Lastrucci et al. [24,25], and Sanz-Muñoz et al. [26] who also found a steep decline in the incidence of respiratory infectious diseases during the COVID-19 pandemic.

Nonpharmaceutical intervention measures put in place during the pandemic affected the transmission of communicable diseases (e.g., respiratory diseases) by limiting human-to-human contact and opportunities for environmental exposure [27]. However, the application of these measures has gradually evolved through the respective waves to be more relaxed [15]. While it is expected that this should result in a rebound in the incidence of respiratory diseases, the data does not support this presupposition. This may also indicate that the relaxations in place are yet to reach the threshold to offset the incidental gains made in the wake of the pandemic. The low incidence is also most likely attributed to the nationwide persistence of masking in public places. Additionally, newly acquired habits such as hand hygiene and the remnants of practices such as physical distancing in public spaces might equally be contributing to the observed trend. These observations are

Table 1
Relationship among respiratory infectious diseases in 2020 and 2021.

Correlation	COVID-19	Influenza	Measles	Pertussis	Pneumonia	Scarlet fever	TB
COVID-19	–		*			*	
Influenza	−0.32	–	***	***	***	***	**
Measles	−0.45	0.97	–	***	***	***	**
Pertussis	−0.35	0.85	0.84	–	***	***	*
Pneumonia	−0.16	0.80	0.77	0.7	–	***	**
Scarlet fever	−0.51	0.79	0.87	0.72	0.69	–	
TB	−0.27	0.55	0.54	0.51	0.60	0.38	–

*Indicating p-values: ***p<0.001, **p<0.01, and *p<0.05.

Table 2
Summary of observed and forecasted incidence of respiratory infectious diseases in 2020 and 2021.

Disease	Observed	Forecasted	Change %	Mann Whitney *U* Test	
	2020–2021[a]	2020–2021[a]		statistics	*p*-value
Influenza	5613	56647	−90	10	*
Measles	53	720	−93	2	*
Pertussis	2	4	−50	61	*
Pneumonia	14542	26028	−44	40	*
Scarlet fever	62	292	−79	8	*
TB	399	434	−8	258	0.543

[a] Mean; *p≪0.05.

not a one-size-fits-all phenomenon as incidence is dependent on the extent and nature of non-pharmaceutical measures. For example, a study conducted in Israel showed an increase in out-of-season respiratory syncytial virus (RSV) following the relaxation of COVID-19 measures [28].

As shown in Table 1, the results of correlation analysis revealed a negative correlation between COVID-19 and the other respiratory diseases. This negative correlation was significant for measles ($p < 0.05$) and scarlet fever ($p < 0.05$). Within the respiratory diseases, a positive correlation was observed. This positive correlation was significant between influenza and measles ($p < 0.001$), pertussis ($p < 0.001$), pneumonia ($p < 0.001$), scarlet fever ($p < 0.001$), and TB ($p < 0.01$). The correlation between COVID-19 and scarlet fever was the most negative ($R = -0.51$), while within the respiratory diseases, the most positive correlation ($R = 0.97$) was observed between measles and influenza. A myriad of reasons besides intervention measures which limited the risk of infections might have led to this and other scenarios of positive correlation. One of the means by which the spread of measles is prevented is by administering vaccines. Live attenuated vaccines such as Measles-Mumps-Rubella and Bacillus Calmette–Guérin have been reported to impart heterologous immunity against deadly infections like pneumonia and sepsis [29]. The windfall to a massive decline in measles cases is a decrease in susceptibility to other infections by certain age-groups, e.g., children to influenza. This is because the immune system's memory is not compromised against other pathogens.

3.1. SARIMA model

Based on the AIC value computed for each respiratory disease incidence, the value for p, d, q, P, D, Q parameters were estimated. The AIC computation showed that the optimal model parameters for influenza, pneumonia, and pertussis were SARIMA (0, 1, 1) (1, 1, 1) 12 and for scarlet fever, measles, and TB was SARIMA (1, 1, 1) (1, 1, 1) 12. The mean absolute scaled error (MASE) in ascending order is scarlet fever (0.44), pneumonia (0.50), measles (0.54), TB (0.62), pertussis (0.63), and influenza (0.67). The MASE value for all diseases forecast is less than one, indicating a better forecast than the average one-step naïve forecast. The details of the model accuracy assessment are provided in Table S3. Moreover, figures showing the observed cases versus the forecasted for the training and testing datasets are shown in Fig. S2.

The overall decrease in the incidence of respiratory diseases when public health measures are imposed as opposed to when they are absent stood at 61% within the 2020–2021 timeframe for observed and forecasted cases. The decrease was largest for measles (93%), influenza (90%), scarlet fever (79%), pertussis (50%), and pneumonia (34%), respectively (Table 2). The drop in influenza cases reported in this study lies within the reported range for influenza cases in China, USA, Japan and Singapore. Huang et al. [30]; noted 60.5%–99.5% decrease in the incidence of influenza during the period of compulsory non-pharmaceutical intervention due to the pandemic. Worthy of note was an 8% decrease in TB cases during the pandemic, which was not significant ($p = 0.543$). This number is close in range to recent analysis that suggests that physical distancing has the potential to decrease TB transmission rates by 10% in high TB burden countries [31]. On the contrary, studies in Serbia and South Korea reported a significant decrease in the incidence of TB in 2020 by 52% and 24%, respectively [32,33]. The authors of both studies among other reasons posit that TB contact investigation deprioritization, increased biased towards COVID-19 screening leading to simultaneous decrease in airborne disease transmission, difficulties seeking medical attention and possible under-reporting are possible factors. Furthermore, both studies did not rule out the contributions of physical distancing and increased mask wearing. It is also reasonable to highlight that Serbia and South Korea are categorized as low burden and intermediate burden TB countries, respectively. In the case of Thailand, a high TB burden country, heightened vigilance in the wake of the COVID-19 pandemic might have led to more diagnoses made. The trend of the unhindered incidence of TB during the COVID-19 pandemic is not unique to Thailand. Recently, Lewer et al. [34] reported that the rates of TB in London, UK were unaffected by pandemic measures. Drawing from the authors of this study, a slight bump in the numbers between 2020 and 2021 suggests a lag in the presentation of symptoms given that TB has a long incubation period which varies widely. Furthermore, public health intervention measures affect different socioeconomic groups differently, with the socioeconomically disadvantaged being the most vulnerable. This reality overlaps with the greater incidence of TB among socio-economic deprived groups [35], who under certain circumstances were cramped in small living quarters during the lockdown, increasing the risk of transmission. Moreover, co-infection with COVID-19 might have also increased susceptibility to TB infection.

3.2. Limitations

A limitation of this study is the absence of daily or weekly data to improve forecasting accuracy of respiratory infectious diseases. Moreover, the study cannot identify which public health measures (face mask wearing, hand hygiene, physical distancing, or lockdown) are the most effective in reducing respiratory infectious incidences.

4. Conclusion

Public health measures implemented due to the spread of the COVID-19 pandemic were associated with a significant reduction in other respiratory infectious diseases among Thais. A 61% average decrease was observed under the imposition of public health measures due to COVID-19 compared with estimates in the absence of these measures. The percentage decrease in the incidence of respiratory infectious diseases in the presence of public health measures as opposed to its absence are 93%, 90%, 79%, 50%, 34%, and 8% for measles, influenza, scarlet fever, pertussis, pneumonia, and TB, respectively. A multiple of factors led to a decline in the reported incidence of respiratory infectious diseases during the COVID-19 pandemic. More challenging to the observed trend following the implementation of public health measures, is untangling the contribution of each of these interventions. A valuable lesson to be learned from the pandemic is the embrace of non-pharmaceutical interventions to curtail the spread of respiratory disease seasonal regulars like the flu. It is also safe to assume that a reduction in hospital admissions or reports does not necessarily equate to a decrease in circulating respiratory disease agents. However, the proactive awareness campaigns by government agencies and compliance of the public ~~to~~ with these rules has greatly limited the transmission of the diseases. Moreover, the effect of public health measures varies among the disease types. Therefore, further work is inevitable to identify those measures that have a greater impact on each disease's transmission.

CRediT authorship contribution statement

Nji T. Ndeh: Conceptualization, Writing – original draft, Writing – review & editing. **Yacob T. Tesfaldet:** Writing – original draft, Writing – review & editing, Visualization. **Jariya Budnard:** Writing – review & editing, Data curation. **Pavadee Chuaicharoen:** Writing – review & editing.

Declaration of competing interest

None.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.tmaid.2022.102348.

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